

A Generic Force Field Method for Robot Real-time Motion Planning and Coordination

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CERTIFICATE OF AUTHORSHIP / ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

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Abstract

This thesis presents a systematic study on a novel force field method (F^2) for robot motion planning and multi-robot motion coordination. In this F^2 method, a force field is generated for each robot based on its status: location, orientation, travel speed, priority, size, and the robot's environment. A robot with larger volume, travelling at higher speed or with higher task priority than other robots, will have a larger force field, and consequently has priority in collision avoidance. The interaction of a robot's force field with its environment provides a natural way for real-time motion planning and multi-robot coordination.

Four novel F^2 based methods have been investigated for applications in different cases. The Canonical Force Field method (CF^2) is first designed based on the concept of the F^2 method, in which a robot is assumed to be travelling with constant speed and its moving direction is determined by the resultant forces acting on it. This CF^2 method has proved to be very efficient in applications in simple and structured environments. A Variable Speed Force Field method (VSF^2) which takes a robot's kinematic and dynamic constraints into consideration is further investigated. The VSF^2 method allows a robot to change its speed based on environmental information and the status of obstacles and other robots in the same environment. A Subgoal-Guided Force Field method (SGF^2) is developed to enhance the F^2 method by generating subgoals based on updated sensor data. A robot using the SGF^2 method will then move towards a subgoal instead of the global goal, which greatly broadens the applicability of the F^2 method in more complex environments. Finally, a Dynamic Variable Speed Force Field method ($DVSF^2$) is designed for applications in partially known and dynamically changing environments. In this method, subgoals are selected on a pre-planned global path.

In order to investigate the effect of parameters on the performance of the proposed F^2 methods, two optimization algorithms have been proposed in this research for optimal design of the parameters in F^2 methods: the Particle Swarm Optimization-tuned Force Field method (PSO-tuned F^2) for single objective parameter optimization and the Ranked Pareto Particle Swarm Optimization approach for multiobjective parameter optimization.

Extensive simulations and experiments with real robots in an indoor environment have been carried out to verify these methods. The results have demonstrated the feasibility and efficiency of the F^2 methods in real-time robot motion planning and multi-robot coordination in various environments.

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